MULTIFUEL INFRARED BURNER WITH ADJUSTABLE METERING VALVE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application serial no. 08/654,967 filed May 24, 1996, now allowed ~~currently pending~~, which was a continuation-in-part of application serial no. 08/272,819 filed July 11, 1994, now issued as United States Patent 5,527,180 and dated June 18, 1996 which, in turn, was a continuation-in-part of application serial no. 08/089,763, now issued as United States Patent 5,391,075 and dated February 21, 1995.

INTRODUCTION

This invention relates to a burner and, more particularly, to an infrared burner utilizing an air aspirated nozzle, a fuel-holding tank, a regulator interposed between the fuel holding tank and the nozzle and an adjustable metering valve to increase or decrease the fuel supply to the air aspirated nozzle.

BACKGROUND OF THE INVENTION

It is desirable in many applications to have a burner which will operate using a plurality of fuels. Such a burner is described and claimed in Reissue U.S. Patent 28,679 naming the same inventor as named in the present application. The use of a multi-fuel burner is desirable because it may be operated with fuel as is readily available in the operating environment where the burner is utilized.

For example, in the high north, construction and mining equipment may operated with diesel fuel. It is convenient to use such a fuel for operating the burner.

The burner illustrated and disclosed in Reissue Patent 28,679 and in U.S. Patent No. 5,102,328, however, utilize in the first instance a round flame grid and, in the second instance, a cylindrical flame grid which are convenient for the particular applications under which they may be used. In other applications, however, it is convenient to utilize a flame grid having a different configuration which may be designed and manufactured for far less expense and which may be used, for example, for water heating and for oven heating, which oven may be used in a field kitchen by the military. A furnace may also utilize the burner which furnace distributes the hot air by using appropriate ducting.

Heretofore, the multi-fuel burner according to the aforementioned patents has used an ignition electrode to provide for the initial combustion of the atomized liquid fuel which is emitted from the nozzle by the venturi action of the primary air in the nozzle. Ignition electrodes, however, have a gap in which the distance is critical. The tips of such electrodes can also burn off until the electrode eventually becomes inoperable and a relatively high amount of power is required to form the spark on the electrode. Thus, relatively high maintenance is required to keep the ignition electrode in optimum condition and replacement is, of course, required from time to time.

Although igniters have been used with gaseous systems such as propane as described in U.S. Patent 3,875,477, it has not been contemplated that an igniter may be used with atomized liquid fuels. Although propane is stored in a liquid form, when the pressure is released on the liquid, the propane is ejected by the nozzle in gaseous form. The propane will be ignited when it passes over the igniter.

The place of introduction of secondary air is important. For example, if it is desired that combustion occur on an external grid rather than internally of the burner tube, the secondary air is added at a location where it supports combustion on the grid and not within the burner tube.

In our United States Patent 5,527,180, dated June 18, 1996, the contents of which are incorporated herein by reference, there is disclosed an infrared burner with an air aspirated nozzle, a zero pressure regulator which regulates the fuel flow from the fuel tank to the air aspirated nozzle and a fuel pump which regulates the fuel flow to the air aspirated nozzle. The teachings of the '180 patent are useful in many applications and the apparatus there disclosed works satisfactorily for those applications.

However, where there is a larger range of operating energy required, it is difficult to provide a decrease in fuel flow at the low fire operation using a fuel pump. The fuel pump does not operate properly at the low

fire operation to allow a reduction of fuel flow sufficient to obtain the low fire operation. In addition, the fuel pump provides pulsed fuel flow. At higher energy requirements, the fuel flow provided by the fuel pump is sufficient to allow consistent ignition of the fuel. But at low fire operation, the pulsed fuel flow is exaggerated with the result that fuel combustion is somewhat inconsistent. In addition, by reducing the power to the fuel pump to obtain the decrease in fuel flow, the fuel pump would simply quit operating under certain power applications.

In addition to the operating difficulties at low fire, the fuel pump of the '180 patent is controlled electronically. The burner according to the present application and the '180 patent is required to be used in field facilities where it is not treated delicately. Electronic controls can easily be damaged and, of course, electronic controls are complex and costly.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, there is provided an infrared burner assembly comprising an air aspirated nozzle, a compressor to provide air to said air aspirated nozzle, a fuel supply to supply fuel to said air aspirated nozzle and a metering valve interposed between said fuel supply and said air aspirated nozzle, said metering valve being adjustable to increase or decrease the fuel supplied to said air aspirated nozzle from said fuel supply.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Specific embodiments of the invention will now be described by example only, with the use of drawings in which:

Figure 1 illustrates a burner according to the invention having a burner tube in which combustion takes place with a nozzle holder connected to the end of the burner tube in accordance with the present invention;

Figures 2A and 2B are sectional and end views of the nozzle holder according to the invention taken along IIA and IIB of Figure 1, respectively;

Figure 3 is an exploded view of several of the operating components of a hot water heater into one end of which is inserted a burner according to Figure 1; and

Figure 4A is a view of the burner according to the invention utilizing a rectangular flame grid and baffle in a furnace or oven heating application;

Figure 4B is a view of the baffle within the burner tube taken along IVB-IVB of Figure 4A;

Figure 4C is a plan view of the rectangular flame grid of the burner according to Figure 4A;

Figure 5A is a side, partially sectioned diagrammatic view of an infrared burner accordingly to a further aspect of the invention;

Figure 5B is an end view taken along VB-VB of Figure 5A;

Figure 6A is a side view of an inner tube which is used within the burner tube of Figure 5;

Figure 6B is an end view taken along VIB-VIB of Figure 6A;

Figure 7 is a diagrammatic side view of a heater body with a chimney and chimney collar according to a further aspect of the invention;

Figure 8A is a side view of a heat exchanger used with the burner of Figure 1;

Figure 8B is an end view of the heat exchanger of Figure 8A taken along VIIIB-VIIIB of Figure 8A;

Figure 8C is a diagrammatic view of the heat exchanger of Figures 8A and 8B showing the water circulation therein;

Figure 9 is an exploded isometric view of the burner according to an embodiment of the invention;

Figure 10 is a schematic view of the operating components of Figure 9;

Figure 11 is a schematic illustrating a further embodiment of the present invention wherein an adjustable metering valve is used between the fuel supply and the air aspirated nozzle and the fuel tank is operated at ambient pressure at relevant times;

Figures 12A and 12B illustrate further configurations of the infrared burner;

Figure 13 illustrates a further configuration of the infrared burner;

Figure 14 is a diagrammatic view of a burner assembly particularly illustrating the use of a photocell to monitor the presence of absence of the flickering flame;

Figures 15A and 15B are schematic views of the circuitry used with the photocell of Figure 14.

DESCRIPTION OF SPECIFIC EMBODIMENT

Referring now to the drawings, a burner according to the invention is generally illustrated at 10 in Figure 1. It comprises a burner tube 11 with one end having a secondary air injection plate 12. The opposite end 13 of the burner tube 11 is open.

The secondary air injection plate 12 is operably connected to a nozzle holder 14. Nozzle holder 14 is adapted to allow the mounting of a nozzle 20 in one end 15 of the nozzle holder 14 and also to allow an igniter 21 to be mounted on an inclined radial to the nozzle hold 14 as is illustrated. A typical igniter that may be utilized in this application is a NORTON hot surface igniter and, in particular, the NORTON Model 301 igniter which is more completely described, for example, in U.S. Patent 3,875,477 entitled SILICON CARBIDE RESISTANCE IGNITER, the disclosure of which is hereby incorporated by reference. The igniter 21 has a tip 22 which is located a distance from the apex 23 of the nozzle 20 such that when atomized liquid is emitted from the nozzle 20, the tip 22, when heated, allows the atomized fuel to be ignited as will be described.

A plurality of circumferential holes 24, conveniently eight (8) in number, are located about the periphery of the nozzle holder 14 and allow primary air to enter the nozzle holder 14 and to proceed directly, without diversion, to the burner tube 11 as is indicated by the arrows.

A plurality of circumferential secondary air holes 30 are located about the inside circumference of the burner tube 11 and are drilled through the secondary air injection plate 12 in the positions illustrated. A central circumferential aperture 31 allows ingress of the atomized fuel from the nozzle 20 into the burner tube 11 where combustion occurs.

A flame rod 32 is located in the burner tube 11 and is operable to pass current between the flame rod 32 and ground 33 operably mounted across the burner tube 11 so as to indicate the presence or absence of a flame. A voltage source 34 supplies the necessary power to the flame rod 32.

Nozzle 20 has a source of liquid fuel 60 which is provided to the nozzle 20. Compressed air is also provided to the nozzle 20 through a compressed air line 61.

OPERATION

In operation, the igniter 21 is switched on and tip 22 immediately heats to a temperature which will ignite the atomized liquid being emitted from the apex 23 of nozzle 20 under the suction or venturi effect of the compressed air entering line 61 and leaving nozzle 20. The atomized liquid fuel which may be gasoline, jet fuel, waste oil, diesel fuel, heating oil or the like is ignited by the tip 22 of the guide 21 and pass through the centrally located circumferential aperture 31 where combustion takes place within the burner tube 11. Following the ignition of the atomized fuel in the burner tube 11 and the increase in temperature of the burner tube 11 to allow the combustion to be self sustaining, the igniter 21 will terminate operation. The flame rod 32 senses the presence of a flame in the burner tube 11 as is known. In the event no flame is present, the flame rod 32 will immediately act to shut down the burner 10.

The primary air passes radially through the circumferential primary air holes 24 from the atmosphere. It then passes directly to the burner tube 11 as is illustrated by the arrows in Figure 1. The secondary air passes axially through the secondary air holes 30 on the secondary air injection plate 12 and act to support combustion within the burner tube 11.

The nozzle holder 14 is shown in more detail in Figures 2A and 2B. A hole 62 is machined in the nozzle holder 14 to allow the nozzle 20 (Figure 1) to be held by the nozzle holder 14. The primary air holes 24 are located about the circumference of the nozzle holder 14 and are used to allow primary air to radially enter into the nozzle holder 14 and, thence, to pass directly to the burner tube 11.

A further embodiment of an apparatus with which the burner according to the invention is used is illustrated in Figures 4A, 4B and 4C. This embodiment is used, for example, where it is desired to heat an oven such as a stove in a field kitchen as might be used by the military and the like. In this case, the air injection plate 71 will have no secondary holes surrounding the nozzle holder 70 and the burner tube 64 will be located a distance away from the air injection plate 71 as is illustrated. A rectangular or square flame grid 63 faces upwardly and is connected to one end of the burner tube 64. A U-shaped baffle 65 is positioned within the burner tube 64 so that the fuel passes through the baffle 65 on the way to the rectangular grid 63.

The baffle 65 has a centrally located pilot hole 66 and a plurality of holes 67 to allow passage of the fuel to the grid 63. The nozzle holder 70 is mounted directly to the injection plate 71 and, upon the tip of the igniter 72 igniting the atomized fuel being ejected from the nozzle 73 under the influence of air being provided through the compressed air line 74 and the liquid fuel being provided through fuel line 80, primary air enters the primary air holes 81 and passes directly to the burner tube 64 to support combustion of flame grid 63. It will be particularly noted that no secondary air holes are provided in the injection plate 71 because the combustion is not taking place within the burner tube 64, but, rather, on the rectangular flame grid 63. However, secondary air intake holes 68,69 and located in the jacket 76 surrounding the burner tube 64 about the outside circumference of the jacket 76 and the circumference of the end 75 of the jacket 76, respectively.

A further embodiment of the invention as shown in Figure 3 which illustrates several operating components of a hot water heater. The burner accordingly to the invention as illustrated in Figure 1 is inserted directly into the end 85 of the housing generally shown at 82. The burner tube 11 (Figure 1) extends into cylinder 83 and cylinder 83, in turn, extends into the water jacket generally illustrated at 84.

In operation, and upon initial combustion of the atomized fuel within burner tube 11, the cylinder 83 will be

heated. Cylinder 83 will provide heat to the water jacket 90 and the water will be heated.

Instead of a flame rod 32, a photocell could be used which senses the presence or absence of a flame in the burner tube 11.

A further embodiment of the invention is illustrated in Figure 5 which shows an infrared burner generally illustrated at 100 and is useful to increase heating efficiency in many applications. This is accomplished by keeping the flame within the burner tube 111 so far as possible so that the flame heats the burner tube 111 to a red or white hot condition. To that end, the nozzle holder 101, nozzle 102, igniter 103 and the fuel and air inlets 104, 110, respectively, remain identical to those illustrated in the Figure 1 embodiment. Likewise, primary air holes 111 are located in the nozzle holder 101.

However, the configuration of the burner tube 111 departs markedly from that of the Figure 1 embodiment. In the configuration according to Figure 5, it is the intention to keep the flame within the burner tube 111 and a closure member 112 is located at the end of the second portion 121 of the burner tube 111 distant or remote from the nozzle 102. Burner tube 111 has a circumferential configuration and extends axially or longitudinally from an interface 113 between the nozzle 102 and the burner tube 111 to the closure member 112. It has two areas, the first area 114 having a solid circumference and the second portion 121

having a plurality of holes 120 extending therethrough to the inside of the burner tube 111. Holes 120 appear on the top one half of the second portion 121 of burner tube 111 or all the way around the second portion 121 of the burner tube 111. To assist the burner 100 to keep the flame within the burner tube 111 and the outer axial area of the flame near the closure member 112, an inner tube 116 is located within the burner tube 111 principally within the sold or first portion 14 of the burner tube 111.

The inner tube 116 is illustrated in greater detail in Figures 6A and 6B. It comprises first and second flame grids 122, 123, respectively, each with a plurality of holes 124 extending axially therethrough. A central circumferential member 130 extends longitudinally. Inwardly of each end of the circumferential member 130, the flame grids 122, 123 and located.

An orifice 131 is positioned within the member 130. The orifice 131 is tapered as illustrated; that is, it tapers from a first diameter 132 nearest the nozzle 102 to a second diameter 133 which is of a smaller value that the first diameter 132. The orifice 131 is intended to create a low pressure zone which exerts some influence on the flame formation and keeps it near the closure member 112 than extending outwardly from it and the burner tube 111. If the flame is retained within the inner tube 116, there is better heat transfer between it and the flame with the results that the burner tube 111 and particularly the second portion 121 of the burner tube 111 will be heated to a

higher temperature.

Yet a further embodiment of the invention is illustrated in Figure 7. In this embodiment a burner is generally illustrated at 200 with its flame 201 diagrammatically shown. The burner 200 can be of the various configurations including the configuration of Figures 1 - 6 but, regardless of the configuration, it is mounted in a heater body or combustion chamber generally shown at 202 which may be positioned and operated in a shelter such as a tent or cabin (not illustrated) to heat the interior.

A chimney 203 is mounted at the outlet of the heater body 202 and is inserted into a joined outer straight collar 204 and a tapered inner collar 210 which is joined to the outer straight collar 204 by weld 211. Thus, the top 212 of the heater body 202 is flush with the top of outer and inner collars 204, 210, respectively, and facilitates cleaning and handling. Chimney 203 is secured to a grater extent when it is inserted into the circumferential "V" formed between the outer and inner collars 204, 210 and there is little or no possibility of air leakage between the chimney and the collars 204, 210 which would otherwise by the case when using chimney collars of known configuration.

Yet a further embodiment of the invention is illustrated in Figures 8A, 8B and 8C. In this embodiment, the burner assembly of Figure 1 generally illustrated at 300 is mounted within a heat exchanger generally illustrated at

301. A circulating pump 302 provides for water to be introduced t the heat exchanger 301 through inlet 303 and which water exits the heat exchanger through outlet 304 after circulating through the heat exchanger 301 as seen diagrammatically in Figure 8C.

The heat exchanger has a plurality of flutes or hat sections 310 (Figure 8B) located about the circumference of the heat exchanger 301, the flutes 310 having an increased surface area which serves to more efficiently pass heat from the burner 300 to the water and which flutes 310 are made from cast aluminum. The lower one half of the flutes 310 are connected to the circumference of the heat exchanger 301 thereby to form a lower passageway 309 confining the water to the passageways on the lower half of the heat exchanger 301 until the leftward end is reached as illustrated in Figure 8C. A channel or passageway 311 passes the water at the leftward end of the heat exchanger 301 to the upper passageway 312 which thereby confines the water to pass through the upper half of flutes 310 and out through outlet 304 as described.

The use of the heat exchanger 301 allows applications which require hot water. Such applications are well known and include maintaining water within water jackets of an engine in a heated condition thereby keeping an engine heated when otherwise shut down. The heated water could be used for many other purposes as is well known in the art.

A powered multifuel burner colloquially known as a PMB is generally illustrated at 410. An infrared burner assembly 411 is utilized in the PMB and is mounted within a burner well 412. A layer of high temperature insulation 413 is provided between the burner well 412 and a reflective heat shield 414.

An air aspirated nozzle 420 is mounted within the infrared burner assembly 411 and an air tube 421 extends from the air aspirated nozzle to a surge suppressor 422 and, thence, to an air compressor 423. A solenoid valve 424 is positioned between the air aspirated nozzle and the air compressor 423. The solenoid valve 424 is switched on and off to control the passage of air from the compressor 423 to the air aspirated nozzle 420.

A fuel tank 430 is positioned with the frame 431 of the PMB 410 and an air inlet hose 434 extends from the air compressor 423 to the fuel tank 430 where a pressure is applied to the volume within the fuel tank 430 which is above the fuel in the tank 430. An orifice 432 and a bleed valve 433 are operably positioned between the air compressor 423 and the fuel tank 430. The bleed valve 433 is the principal operating control of the PMB 410 and allows a variable amount of air to be bled from air inlet hose 432 thereby to vary the pressure within the fuel tank 430.

A first fuel hose 440 extends from the bottom portion of fuel tank 430 to a fuel regulator 441, conveniently a zero pressure regulator. A second fuel hose

442 extends from the regulator 441 to the air aspirated nozzle 420. An orifice 443 is positioned within the first fuel hose 440 between the fuel tank 430 and the zero pressure regulator 441.

A fuel pump 444 is provided to allow the fuel tank 430 to be filled with fuel prior to operation of the PMB 410.

In operation, the fuel tank 430 is filled with a desirable fuel utilizing the fuel pump 444. Thereafter, the operation of the air compressor 423 is initiated with the solenoid valve 424 in its closed position. Thus, no vacuum is being created at the air aspirated nozzle 420 and no fuel will flow from the regulator 441. Also in this condition, the bleed valve 433 will normally be closed so that full air pressure is provided on the fuel within the fuel tank 430.

The solenoid valve 424 will then be opened to allow full air pressure from the air compressor 423 to be applied to the nozzle 420. This will create a maximum vacuum at the nozzle 420 and on zero pressure regulator 441 which will thereby allow a maximum amount of fuel to pass to the air aspirated nozzle 420, thereby to mix with the air and create the high fire or maximum energy operation.

If it is desired to reduced the energy produced by the infrared burner assembly 411, the bleed valve 433 is merely opened an amount as desired to reduce the air pressure in the fuel tank 430. This will reduce the amount

of fuel passing to the zero pressure regulator 441 and, thereby, to the air aspirated nozzle 420, at the same time reducing the air to the nozzle 420 which, in turn, reduced the vacuum on the zero pressure regulator 441 thus reducing the fuel flow to the nozzle 420. With the bleed valve 433 fully open, the air pressure in the fuel tank 430 and at the nozzle 420 will be at a minimum and energy produced by the infrared burner assembly 411 will also be at its minimum or low-fire condition.

The use of orifice 443 between the fuel tank and the zero pressure regulator 441 is intended to limit the fuel flow at low air pressure in the fuel tank 430. Without the orifice 443, it has been found that with the vacuum on the air aspirated nozzle 420, it is possible that a greater amount of fuel would pass to the nozzle 420 than is desirable to obtain the low fire condition. Likewise, the use of orifice 432 between the compressor and the bleed valve 433 is used to allow a greater air pressure provided to nozzle 420 than to the fuel tank because of the backpressure created by the orifice 432. The orifices 443, 432 are useful for varying design parameters so as to allow the operation of the PMB 410 to take place over a predetermined range as may be required.

In the prototype burner according to the present invention, the low-fire energy output is intended to be approximately 15,000 BTU whereby the high-fire energy output is approximately 60,000 BTU. It has been found that air pressure at the nozzle 420 producing the high-fire output is

approximately 10 psi and the air pressure at the nozzle 420 producing the low-fire output is approximately 3.5 psi. This air pressure is, of course, adjusted by the operation of the bleed valve 33 as has been described.

It is contemplated that either or both of the orifices 432, 433 may be replaced by respective air operated metering valves to reduce or increase the air pressure to the nozzle 420. It is further contemplated that a fuel pump may be replaced by an air operated metering valve between the tank 430 an the zero pressure regulator 441 or between the zero pressure regulator 441 and the nozzle 420.

Yet a further embodiment of the invention is illustrated in Figure 11. In this embodiment, a pressurized fuel tank 500 continues to be used. However, the fuel tank 500 is only subject to a vacuum or negative pressure when the tank 500 is being filled with fuel. A metering valve 501 is adjustable and may be manually controlled to increase or decrease the fuel supplied to the air aspirated nozzle 502. An air compressor 503 supplies pressurized air to the nozzle 502 and a three way valve 504 is connected between the compressor 503 and the fuel tank 500.

In operation, the compressor 503 is initiated and three way valve 504 is opened to allow a vacuum to be created in line 511. Three way pilot valve 512 is opened thereby to allow the suction in line 511 to pass to fuel tank 500. Fuel will flow into the tank 500 through one way

valve 513 until tank 500 is full as sensed by a float (not illustrated) whereupon pilot 412 vents to atmosphere and the fuel tank 500 returns to ambient pressure. Three way valve 504 is then closed thereby isolating tank 500 from compressor 503.

A two way valve 510 may be interposed between the nozzle 502 and the metering valve 501. The valve 510 is opened thereby to allow a vacuum created by nozzle 502 in line 513 which passes to regulator 514, conveniently a zero pressure regulator. The suction in regulator 514 will draw fuel into the regulator 514 from tank 500. The amount of fuel may be adjusted by manually adjusting metering valve 501 thereby increasing or decreasing the heat output from the infrared burner assembly 411 (Figure 9) to which the nozzle 502 is operatively connected.

A plurality of infrared burner configurations may be utilised such as is illustrated in Figures 12A, 12B and 13. In Figure 12A, the burner configuration 600 is not tubelike but, rather, is in the shape of a longitudinal member extending outwardly from the inlet 601 and having holes 602 extending through the longitudinal member. A closure member 606 closes the end of the longitudinal member.

A further embodiment of the infrared burner member is illustrated at 603 in Figure 13. In this configuration, the infrared burner is wider than the embodiment of Figures 12A and 12B and may be used in a different heater

configuration where dimensions are not as controlled. Again a closure member 607 closes the longitudinal member and holes 605 extend through the upper portion of the member 603.

Yet a further embodiment of the invention is illustrated in Figure 14 which illustrates a burner generally illustrated at 700 similar to burner 10 of Figure 1. This burner 700, however, has a photocell 701 connected to the nozzle holder 702 by a bracket 703 as is disclosed in our co-pending application serial no. 08/483,819, the contents of which are incorporated herein by reference. The photocell 701 monitors the presence of the flame 704 within the burner tube 710 which is seen by the photocell 701 through openings 715 which extend circumferentially around the nozzle holder 702 within the burner tube 710 as is illustrated.

The photocell, however, used in prior art devices as a flame sensor was utilised to monitor the presence or absence of a flame 704. Thus, either an off or on signal was provided. If the flame was not present, the photocell would so indicate and the fuel and air supply to the nozzle would each be terminated. However, if the photocell failed, the signal emitted was that for the presence of a flame and the sensor would fail to detect the failure. Thus, the air and fuel supply would continue and there would be an oil buildup in the combustion chamber. This can be a safety hazard, can cause unclean burning when the burner is relighted and is inconvenient to clean. It is clearly

advantageous to monitor the flickering of the flame rather than the presence of the flame itself.

The photocell 701 according to the present invention utilises a circuit illustrated diagrammatically at 711 in Figure 14 and illustrated in greater detail in Figures 15A and 15B. The circuit 711 allows the photocell 701 to monitor the flickering of the flame 704 within the burner tube 710 through open areas 715. The circuit utilises a photocell 701 which is a relatively fast sensor as opposed, for example, to a thermocouple, thermistor or photoresistive cell. A flame rod and phototransistor are also contemplated to be useful for this application. The sensor will have a response rate sufficient to detect the "flicker" of a flame and the spectrum surveyed by the photocell 701 will be appropriate for the flame produced according to the application.

The signal from the photocell 701 is then passed through a DC blocking capacitor 116 (Figure 15B) of the circuit 711 wherein the AC signal riding on a DC level is left and the DC component of the signal is removed such that only the AC component of the signal remains. The sensor 701 receives its DC bias through resistor R1. In normal operation, this results in an average DC voltage at "A" of anything from 2 volts to 6 volts DC with a voltage source of 8 volts. It is contemplated that the bias source R1 may be conveniently replaced by a constant voltage source or constant current diode.

By using a high speed detector, in this case a photo transistor used in the photoconductive mode, at point "A" in Figures 15A and 15B, there will be an AC voltage of approximately 1 volt peak to peak. In practise, this varies from about .5 volts to 3 volts at random. This is a variability in flame brightness commonly known at the flame "flicker".

The AC component of the signal is passed through the capacitor C1 to point B. At this point, the DC part of the signal is substantially removed. The AC signal will vary, on average, from about +0.5 to -0.5 volts. If the signal goes to a higher level than -0.6 volts, the amplifier UIA may be damaged. Therefore, a diode D1 is included to protect the amplifier when it is operating on a single supply voltage.

The AC signal is then amplified by amplifier UIA. When the signal at "C" exceeds 0.6 volts, the voltage at point "D" begins to rise. When this voltage exceeds the Voltage Reference at "F", the output of the detector "E" changes state and the circuit supplies a signal to other circuitry giving an indication of flame present.

Since the flame is flickering, the voltage at "C" is not constant but, rather, it rises and falls. Therefore, it is desirable that the signal at "E" only indicate "no flame" when the AC signal has stopped for several seconds. Therefore, the signal at "D" is held by capacitor C2 acting as an energy storage device. This reverse blocking is done

by D2. The voltage at "D" only rises when the voltage at point 'C" exceeds the voltage at "D" by 0.6 volts. Otherwise, the voltage at "D" is held.

To allow the sensor to detect a loss of signal at points "A", "B" and "C", the voltage stored by C2 at "D" is discharged by R5. If the AC signal stops, the charge on C2 will be drained away by R5 in several seconds, causing the detector, UIB, to indicate a loss of flame or other fault in the burner.

While specific embodiments have been described, such descriptions should be taken as illustrative of the invention only and not as limiting its scope. Many modifications will readily occur to those skilled in the art to which the invention relates and, accordingly, the scope of the invention should be construed in accordance with the accompanying claims.